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ABSTRACT

The major focus of this unit is on changes where substances do not, from the scientific viewpoint, actually change into other substances. For example, substances may expand or contract upon heating or change form (such as ice to water). Part 1 provides a 12-item instrument to enable teachers to check their own ideas about this topic and to clarify children's views before and after instruction. Part 2 discusses scientists' views on changes produced by the heating and cooling of substances. Part 3 contrasts scientists' views with children's views of four common events, using comments obtained from the in-depth phase of the Learning in Science Project. Events considered focus on: boiling; steam and condensation from steam; water condensing on a cold surface; and melting ice. Part 4 consists of suggested teaching activities designed to build on and reinforce children's views where these views are essentially similar to those of scientists. An overall framework to the sequence of activities (in flowchart format) is included. (JN)

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Heating and Cooling

A Resource Unit for Teachers.

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WORKING PAPER NO.38

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HEATING AND COOLING

A Resource Unit for Teachers

Brendan Schollum¹, Roger Osborne and John Lambert

CONTENTS

Part 1	Introduction	Page 1
Part 2	A Scientist's View	Page 7
Part 3	Children's Views	Page 10
Part 4	Suggested Teaching Activities	Page 21

PART 1

INTRODUCTION

When one heats or cools something a variety of things can happen:

- (i) the thing doesn't really change at all (eg. it expands or contracts) or simply changes into a different form of the same thing (eg. ice to water)
- (ii) the thing changes into another thing or things (eg. sugar on heating).

In this paper we want to consider the first of the above only. However it is not easy for children to distinguish between the two so we need to keep this in mind when we teach this topic. For example how could children know from everyday experience whether when water boils it changes its form or changes into something else?

1. Other teachers helped with activities for this unit. They include Alison Cosgrove, Terry Meldrum and Peter Scott. Part 3 of this paper is adapted from LISP Working Paper No. 26, PHYSICAL CHANGE by Mark Cosgrove and Roger Osborne.

Children however do have views about what happens when things are heated or cooled from a young age. Children all know about ice blocks, what happens if they are not eaten quickly enough. Similarly they know that when frozen peas are placed with water in a saucepan, the ice melts. When heated, the peas and the water get warm, then hot, and finally the water boils.

Children are familiar with things changing temperature, with solids becoming liquids, and liquids becoming gases. However the examples from everyday life are limited. What are children's views regarding these types of changes, what are scientists views of these changes, and what are your views as a teacher?

If children's views differ from those of scientists how do we modify children's views to enable them to appreciate the consensus scientific views and to possibly adopt that view as their own.

In this paper (Working Paper No 38) we will consider changes where things do not, from the scientific viewpoint, really change into other things. In two other papers (Working Paper No 36 and No 37) we will consider phenomena where things do change into quite different things.

In the first section of this paper you are provided with a survey to enable you to check your own ideas about this topic. The survey is designed to clarify the views of children in your class, nevertheless we have found it provokes much staffroom discussion when a group of teachers attempt it!

In the second section of this paper the consensus scientific views about changes produced by heating and cooling, but which do not involve things really changing into other things, are considered.

In the third section children's views on aspects of the heating and cooling of water, the one substance children are really familiar with, are considered.

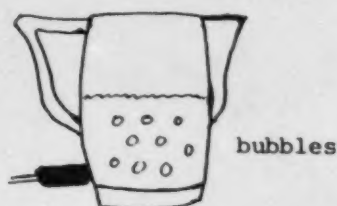
The fourth section of the paper sets out some possible teaching strategies based on the earlier sections, which attempt to build on rather than ignore children's views.

The following questions are about things that happen in the home.

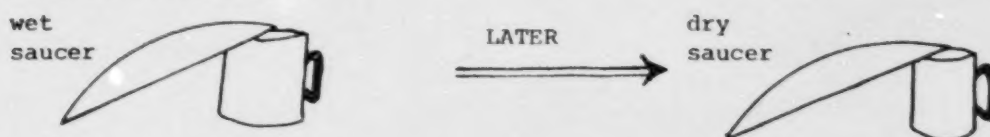
1. When a kettle boils there are large bubbles in the water.

What are the bubbles made of?

- (a) Air
- (b) Steam
- (c) Heat
- (d) Oxygen or hydrogen

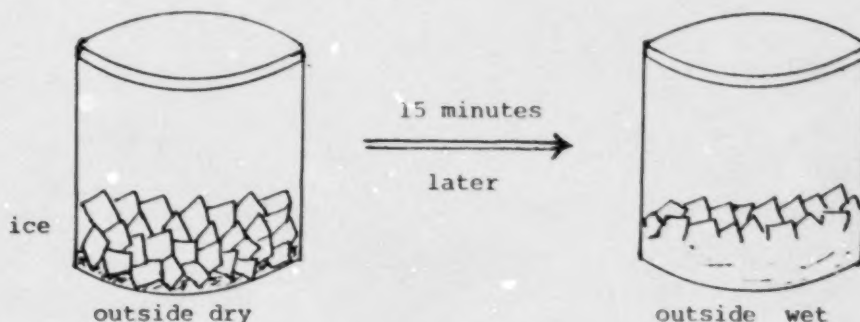


2. If a wet saucer is left on the bench after it has been washed then after a while it is all dry.



What happens to the water that doesn't drip on to the bench?

- (a) It goes into the saucer.
 - (b) It just dries up and no longer exists as anything.
 - (c) It changes into oxygen and hydrogen in the air.
 - (d) It goes into the air as very small bits of water.
3. A small jar is filled with ice, the lid is screwed on tightly, and the outside of the glass is dried with a tea towel. Fifteen minutes later the outside of the jar is all wet.



Where has the water on the outside of the jar come from?

- (a) The water from the melted ice comes through the glass.
- (b) The coldness causes oxygen and hydrogen in the air to form water.
- (c) Water in the air sticks to the cold glass.

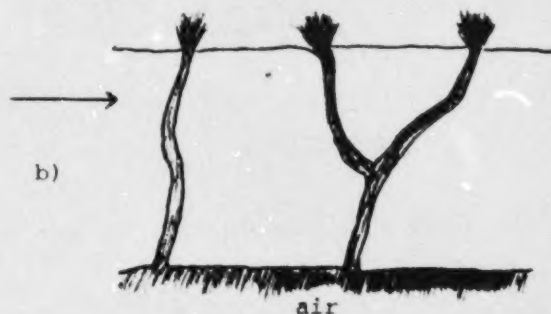
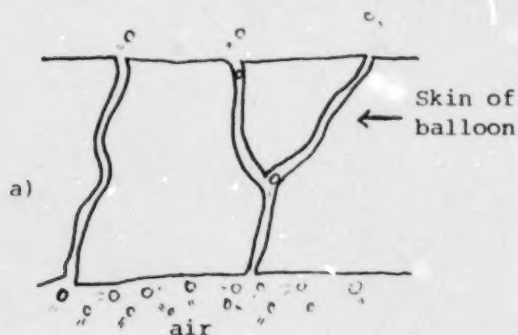
4. A balloon will go down on its own if left for long enough.



Which is like the way you think about it?

air particles escape through very tiny holes in the balloon.

air squeezes out like toothpaste through very tiny holes in the balloon.



5. We smell the scent from flowers easily. Which diagram is most like the way you think about how this happens?



particles from the flower spread through the room and the nose detects these particles.



the scent streams out but no particles leave the flower.

The following questions are about familiar substances which are solids, liquids or gases.

6. When a thermometer is put in hot water, the liquid of the thermometer (often mercury) rises up the tube. The reason for this in your view is:-
- (a) the liquid is made up of particles which get bigger as the liquid is heated.
 - (b) the liquid is made up of particles which move round more and spread out.
 - (c) the liquid is not made up of particles.

5.

7. One way to show air in a bottle is like this.



A boy tries to suck all the air out of the bottle, and he manages to suck half the air out

After half the air is sucked out, he sticks his finger over the end to stop any air getting back in. Which diagram best shows how you would picture the air left in the bottle?

(a)



(b)



(c)



(d)



8. Which do you think is the best reason that the particles of the air in the flask do not fall to the bottom of a flask?

- (a) The particles are always moving about.
- (b) The particles are packed in so tightly that they are unable to fall.
- (c) Air keeps the particles from falling.
- (d) The particles are so small gravity does not affect them.

9. In a flask containing air, what is there between the particles?

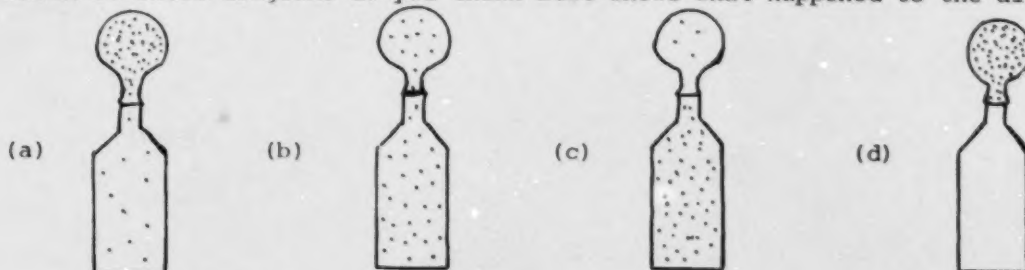
- (a) Air
- (b) Nothing at all
- (c) Gas
- (d) Oxygen

10. A balloon is put over a bottle that contains nothing but air. The air is shown by the dots.

When this bottle is placed in hot water the balloon fills out.



Which of these diagrams do you think best shows what happened to the air?

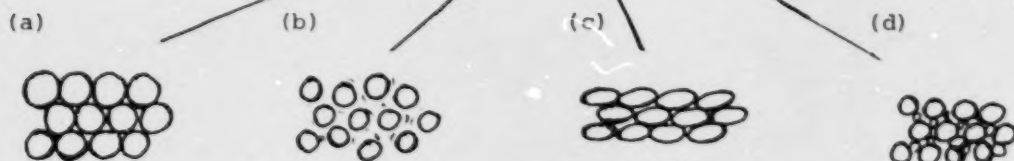


11. If we heat a solid we find it grows slightly bigger (if it doesn't melt!) One way we could picture the finest detail of the solid is shown:

Which shows best what you think happens when the solid is heated and gets bigger.



Solid particles



(a) the particles grow in size

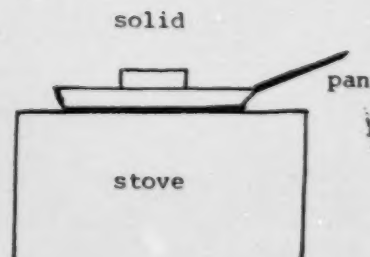
(b) the particles move round more

(c) the particles stretch out

(d) more particles are made by the heat

2. When a solid is placed in a frypan and heated on a stove, which of the following could happen? (You can choose more than one answer if you want to).

- (a) The solid just gets hot
- (b) The solid melts
- (c) The solid gets bigger
- (d) Bits of the solid break away from each other
- (e) Bits of the solid change into new substances



PART 2 A SCIENTIST'S VIEW

From a scientific point of view all matter is made of solids, liquids, gases or plasma, and consists of atoms in regular array or groupings, atoms in random array, and bits of atoms. Apart from these things there is nothing.

In solids the atoms or groups of atoms (molecules) are generally in regular array and the position of each atom is relatively fixed with respect to any other atom. When a solid is heated, but remains a solid, the random vibrations of the atoms increase but the atoms remain fixed in position, although on average the distance between atoms increases slightly (the solid expands). At a certain specific temperature the atoms or groups of atoms (molecules) gain sufficient motion that they are no longer locked in a particular position, and they can move with respect to each other; we have a liquid. The average distance between the atoms or molecules in the liquid state may be slightly more or less than in the solid state. As the liquid is heated, the vigour of the random motion between atoms or molecules increases and the average distances between the atoms or molecules increases slightly (the liquid expands). At a second specific temperature (boiling temperature) the atoms or molecules are no longer a relatively fixed distance apart but move much more freely and independently of each other. The atoms or molecules move out from the original liquid to fill the space available; we have a gas. Sometimes the liquid changes to a gas inside the liquid forming bubbles of gas, the same atoms or molecules as before but much more spread out. As a gas is heated, then if it is in a fixed volume container it effectively pushes harder on the walls of the container, if a part or all of the container is free to move then the gas expands.

If a solid, liquid or gas consists of a particular grouping of atoms, then at a certain temperature and in certain conditions, for example, when heated in the presence of oxygen, the basic grouping may break down or change and we have a different thing or things. In this paper we are not dealing with this type of change (sometimes called chemical change). What we are dealing with is situations where the basis 'building block' remains intact and the only change undergone on heating is a change in the movement of the particles. This may include a change of form (eg. ice to water to steam).

In a metal, or in a gas at extremely high temperatures, atoms can break down into even smaller pieces called ions and electrons. The gas has changed into what is called a plasma.

In this paper we are not concerned about changes where molecules change into other molecules or separate atoms, nor are we concerned about changes where atoms break into ions and electrons.

One of the most common of the type of changes we want to consider here, and the most familiar to children, are the changes caused by the heating and cooling of water. [Unfortunately, as we shall see, children often do not consider these changes to be of the change-of-form only type.] It is for this reason that we now discuss water in greater detail.

From a scientific perspective water consists of molecules, and when water is heated these molecules vibrate and move more rapidly. Eventually if sufficient heat is applied, the molecules are moving so rapidly that the liquid changes into a gas. Under the water surface this gas forms into large bubbles consisting of water molecules - bubbles of steam. On the surface of the water the molecules of water escape into the air, as does the steam released when the bubbles of steam reach the surface.

In view of our later discussion about children's ideas two aspects of the scientists view of steam need to be made clear. First, steam is essentially a gas made up of water molecules. Each water molecule retains its structure and does not break into its constituent parts (hydrogen and oxygen). Secondly, steam consisting of individual water molecules is invisible. However, if large numbers of water molecules combine together to form small drops of water then these are collectively visible. Hence we 'see' the steam above boiling water.

When water evaporates from a wet surface then molecules of water move into the air. However again they remain as water molecules and do not break into hydrogen and oxygen. When water molecules, or "little wee bits of water in the air each so small you can't see them", collide with a cold surface they are likely to lose energy and remain on the surface. Eventually the surface appears wet (condensation). If the air is dry, that is, it contains no water molecules, then condensation cannot occur.

When water freezes the vigour of the random motion of water molecules decreases. The forces between molecules has a stronger influence on the position of individual molecules and the molecules become locked into a rigid structure. According to simple molecular theory it might be expected that the average distance between molecules will be less in solid form than in the liquid form. Somewhat surprisingly this is not so, and water expands on freezing.

We are now in a position to compare these views with those held by children.

PART 3 CHILDREN'S VIEWS ABOUT SOME CHANGES CAUSED BY HEATING AND COOLING THINGS

As you will see as you work through this section, children (and many adults!) have strong views about many of the changes which scientists refer to as physical changes. These views are summarised below. The page numbers refer to more detailed descriptions in other parts of this paper.

Children's Science	contrasted with	Scientist's Science
When water boils or evaporates:		When water boils or evaporates:
- the water changes into air (P15) - the water changes into hydrogen and oxygen (P16) - the water ceases to exist (P15)		Very small particles of water move away from the rest of the water and move about amongst the particles of the air (made up of particles of oxygen and nitrogen mainly) (P8)
When water is seen as condensation:		When water is seen as condensation:
- it is sweat that is formed (P13) - hydrogen and oxygen in the air recombine to form water (P14) - water comes through a container (eg. a jar of melting ice) (P16)		Very small particles of water have come together from contact with a cold surface (P8)
When ice melts:		When ice melts:
- it evaporates into water - the heat makes the particles move further apart (P19) - ice changes to a different substance		Particles of water do not remain locked in a rigid order, where they move about only slightly, but are able to move about more easily within a given volume
When a substance expands:		When a substance expands:
- each of the bits which make up the substance get bigger - heat causes new substances to form - the substance just stretches out		The particles of the substance move round more, taking up more space as they do so
Colour is locked inside coloured substances		The colour of a substance is caused by some or all of the particles of the substance reflecting certain colours of light
When the smell of a substance is detected, the substance has changed into smell		When the smell of a substance is detected, it is tiny particles of the substance that are detected

The children's views described in greater detail here were gained in a series of interviews involving children and events such as watching a kettle boil, observing the condensation of steam on a saucer held above the kettle, and the melting of ice. We will consider the children's view about each event.

3.1 Boiling

In response to the question "what do you see in the electric jug?" as the water approached boiling it was interesting to compare younger children, notably children aged about eleven, described what was happening in greater detail. These were the children who noticed that bubbles formed near the element often collapsed before reaching the surface. Perhaps the older children thought the task too trivial. However these responses were more aligned with what they anticipate will happen "the bubbles come up to the surface and break".

The initial question was followed by "what are the bubbles made of?". The responses to this question suggested that there are four commonly held views.

View 1 The bubbles are made of heat (S4, F2, F4)²

This view was held by three younger pupils, although with at least one pupil, the idea was not held too strongly,

"I don't know. (Haven't you thought about that before?)
No ... just bubbles. (What do you think they could be made of?)
Heat". (F2)

View 2 The bubbles are made of air (S2, S4, F1, 5xF2, 2xF3, F4, 2xF5, F6)

This was a prevalent view. While some pupils considered that the bubbles acquired the air from above the water surface,

"(What are the bubbles?) Air pockets ... Hot air rises, grabs the air and takes it back to the element. When the water come up to the surface, it cools and will go down again and might have sort of trapped some air in it ..." (F6)

-
2. S4 means one Std 4 pupil held this view. S4 after a quote means the words were spoken by a S4 pupil, etc. There were 43 pupils interviewed; 2 x S2, 7 x S4, 1 x F1, 6 x F2, 9 x F3, 4 x F4, 6 x F5, 5 x F6, 3 x F7.

A much more common view was that the air was somehow produced by the water.

"The heat of the element could turn some of the water into air ..." (F2)

View 3 The bubbles are oxygen or hydrogen (2xF4, 2xF5, 2xF7)

Some older students, not illogically, integrated their knowledge about water being made of oxygen and hydrogen, and air consisting of oxygen and other gases, into their earlier view that the bubbles were made of air produced by the water.

"(How do you see what's going on?) Separating I suppose ... the hydrogen and the oxygen ..." (F5)

"(What are the bubbles?) Air pockets. (Bubbles of air?) Yes. (So where has the air come from?) The water, it is made up of oxygen and other elements in the air. (Water is made of oxygen?) Oxygen, hydrogen and nitrogen, and its also got helium and a few other things. (That's inside the water?) Well, it's in the air, but in the water these things do also exist". (F5)

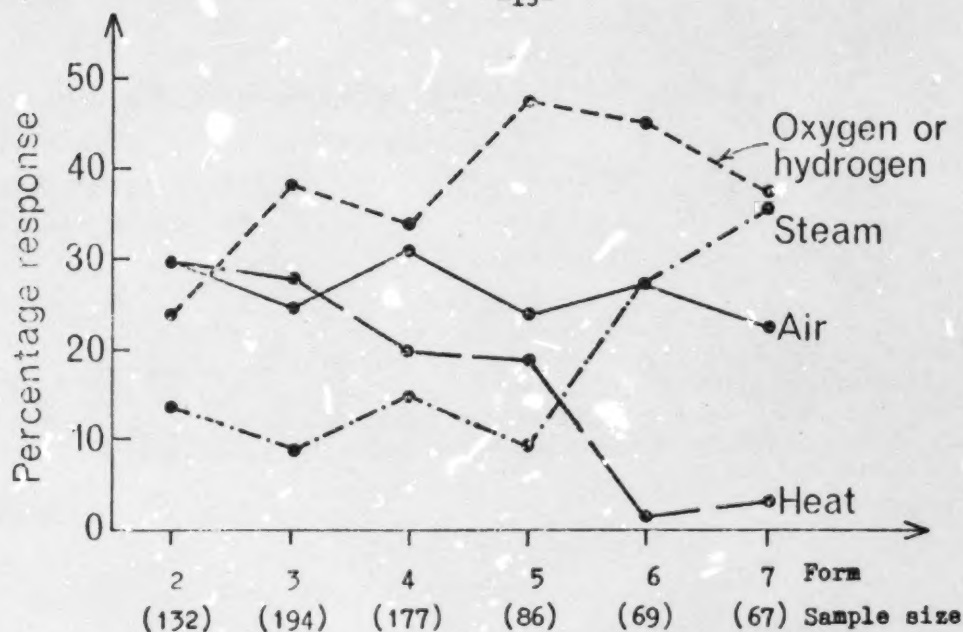
View 4 The bubbles consist of steam (F4, F5, F6, F7)

The final main group of viewpoints is the acceptable scientific view that the bubbles (at least all the large ones!) consist of steam.

"(What are they? (the bubbles)) Gas escaping. Water turning into steam. Well, the bubbles, when they burst, it's water being turned into steam, and that's why they're escaping. (How did the bubbles form?) Molecules moving around, they're getting faster and faster, and they want to break out because ... they're strong enough to break out". (F7)

To gain some indication of the prevalence of these four viewpoints, survey question 1 (and others) were used with a representative sample of pupils.³
What are the bubbles made of?

-
3. All the Form 5 pupils were studying science. All the Form 6 and 7 pupils were studying chemistry. One is left to conjecture how much of the increase in prevalence of the consensus scientific view at Form 6 and 7 was due to teaching at that level, and how much was due to pupils with the scientific view at an early age opting for chemistry at the senior school levels.



3.2 Steam and condensation from steam

Following the discussion of boiling the focus of the interview shifted to the steam and the condensation of the steam on the plate. Seven pupils (2xS4, F2, 3xF3, F5) thought that air and steam were the one thing, but the other pupils considered steam to be water or 'kinda like water', or water in a different form. However, many of these pupils considered that when steam was no longer visible it had changed into air.

To the question "what is this (stuff) on the saucer", or "what has happened here?", these views were apparent:

View 1 "It has all gone sweacy" (3xS4, F3)

A few younger children had rather human centred viewpoints. For example:

"... It's hot and it's just like you're running and your sweat in that its hot ... and it's just gone on to the plate ... you get all hot and sweaty just the same as the plate". (F3)

View 2 "The steam makes the plate wet" (S4, 2xF2, F3)

To these children the steam had made the plate wet, but they had little idea of the mechanism. For example:

"...it's gone wet and warm with the steam ... the hot air ... the steam ... was going around it and it was getting hotter which made it wet ... (where did the water come from?) the steam but I don't know how" (13)

View 3 "The steam changes back into water" (F1, 2xF2, F3, 2xF5, 4xF6, F7)

The majority of pupils interviewed considered that the steam changes back to water on the plate. However this water was not always the same as the water we started with in the kettle.

"(You reckon that's water - same as the water in the kettle or different water?) Different water. (Different water? How is it different?) I don't think we drink this kind of water. (You wouldn't want to drink this?) No (Do you reckon there's something wrong with that water?) Well, I don't think anybody drinks steam water". (S4)

Eleven of the pupils mentioned that heat loss was involved.

View 4 "The hydrogen and oxygen in the steam recombine to form water" (F4, F5)

"... the atoms of oxygen and hydrogen are rising up from the water (separately) yes separately and when they hit something they sort of join together and form little drops of water" (F4)

View 5 "The steam has cooled and the water molecules have moved closer together" (F3, F4, F5, 2xF6, 2xF7)

Seven students explicitly stated a relatively sound scientific viewpoint involving a particle model of some description

"The cold plate has condensed the steam ... the steam has cooled ... and the atoms and molecules are closer together" (F4)

Generally, most children could answer "condensation was happening", but when asked what that meant, the majority of pupils showed very little real understanding. Further, ideas to do with particles moving and colliding were ostensibly understood by older children but continued probing did not produce sound scientific explanations in terms of intermolecular forces and loss of kinetic energy.

3.3 Water Evaporating off a plate

The water which had condensed on the plate, in the event described above, evaporated off the plate when placed to one side. The focus question here was "what has happened to the water". Again many pupils could reply that "evaporation" had taken place but few students had a sound appreciation of

what scientists think happens to the water. Let us consider the range of reasonably prevalent views.

View 1 "It has gone into the plate" (3xS4, F4)

View 2 "It has just gone ... it has dried up" (S2, 5xS4, F2, F3, F5, F7)

To many of these children questions such as "where has the water gone to" or "what has the water changed into" were not relevant; the water hadn't gone anywhere or changed into anything, it had simply ceased to exist.

View 3 "It goes into the air and comes back as rain" (S4, F2, F3, F4, 5xP5, 2xF7)

Pupils who held this view appeared to have some idea that the water went into the air and that it would eventually reappear (as rain for example).

"... the heat in the air gets around it and makes it dry ... probably steam come up from the plate but you can't see it (where does it go?) to the clouds in the sky ... when the clouds get full it rains". (F2)

Eight of the above pupils introduced the term molecules or particles to explain their view.

View 4 "It changes into air" (F2, 2xF3, 2xF4, F5, 5xF6, F7)

Younger pupils simply considered that the water had changed into air. For example,

"... it is sort of sucked up into the air (is it still water?)
no. (what does it change into?) Air. (F2)

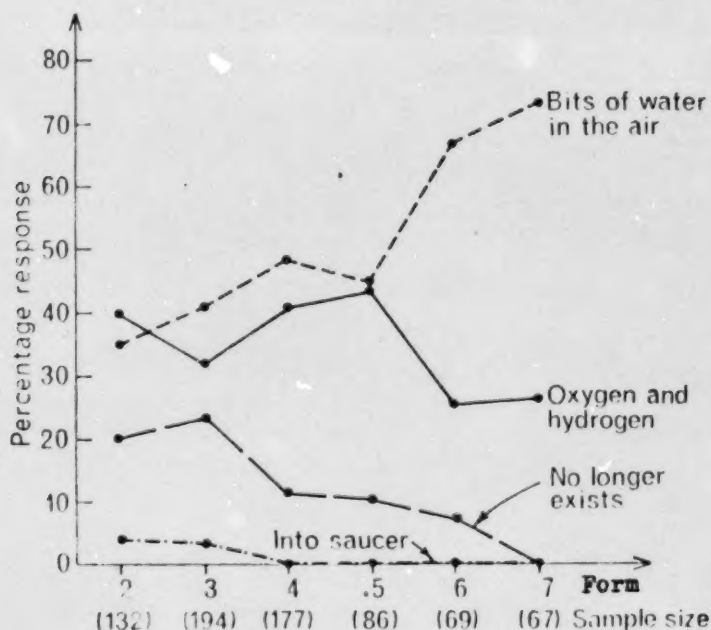
However the older students were able to support this intuitive view, with their scientific knowledge that "water is made up of oxygen and hydrogen" and "air consists of oxygen and other gases".

The consequence of the juxtaposition of their earlier viewpoint, and the above knowledge is not hard to predict. For example,

"... into the air ... it doesn't go into steam ... it just dries up ... (Where is it now?) Not in the steam form because it doesn't look if it has gone up in the water state - it must have split up because you couldn't sort of see steam or anything rising. (So when you say split up ... what do you mean by that?) Into the hydrogen and the oxygen molecules ... the water molecules break into their separate atoms". (F5)

To obtain an indication of the prevalence of this oxygen and hydrogen viewpoint, survey question No 2 was used. The results were⁴:

What happens to the water that doesn't drip onto the bench?



3.4 Water condensing on a cold surface

Each child interviewed had been shown ice in a small jar. The lid was screwed on and the child dried the outside of the jar until he/she considered it to be dry. The jar was then set aside for some 20 minutes while other parts of the interview schedule were proceeded with. The focus question here was (after the liquid which appeared was recognised as water) "where has the water on the outside of the jar come from?" Let us again consider the range of views held by the children interviewed.⁵

View 1 "The water comes through the glass" (2xS4, F2, 2xF3, F4, 3xF5, F7)

One student with this view was able to support the view with some knowledge of science

-
4. We need to keep in mind that these results provide only a rough indication of the pupil's own views. Undoubtedly some children may choose the alternative which sounds the most "scientific".
 5. It should be pointed out that some pupils interviewed were really puzzled by the phenomena and six pupils (S4, F1, F2, 2xF3, F6) really had no clear views.

"Oh well, it must have gone through the glass ... the particles of water they have gone through the glass ... like diffusion through air and that ..."

LATER

"(A lot of people I have talked to, younger children, are very worried about this, it troubles them a lot.) Yes, because they haven't studied the things like we have studied. (What have you studied which helps you?) At school? (Yes) Things that pass through air, and concentration, and how things diffuse". (F5)

View 2 "The coldness has come through the glass and produces water"
(S2, 5xS4, F3, F5)

To some of the young children the whole phenomena was simply explained in terms of the coldness trying to get out; differences between coldness and cold water did not appear to be appreciated. To other children the coldness manufactured the water on the jar exterior,

"... it is so cold in there that all the cold is coming out here onto the glass ... it is just so cold that it is just making it so the outside is cold ... the water is just being made there". (F2)

View 3 "The cold surface and dry air react to form water" (3xF2, 2xF4, 5xF5, F7)

Although one or two younger children put forward this view, it was a view which was more prevalent with older students who supported their view with knowledge about oxygen and hydrogen.

"... the atoms of hydrogen and oxygen bombarding the glass and the coldness of it sort of makes it stick there ... the coldness is coming out of the glass and it might even attract them ... the molecules of the two gases (oxygen and hydrogen) are sort of frozen there". (F4)

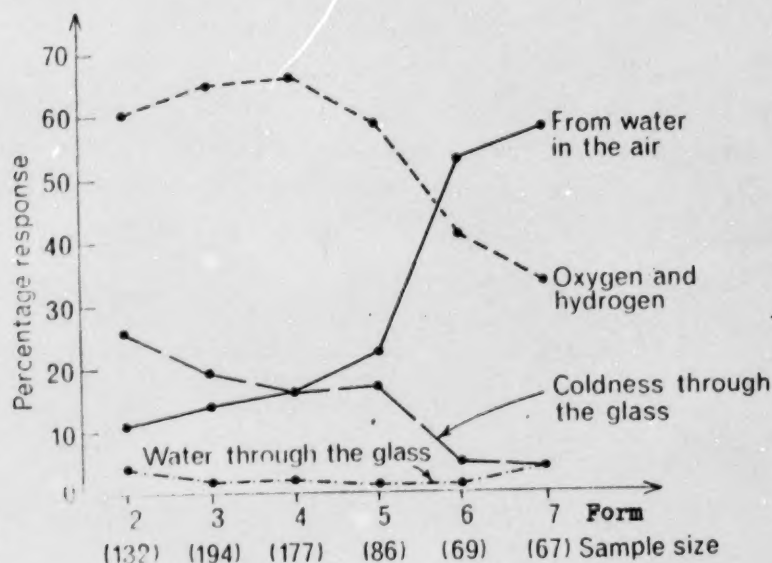
"... it could be oxygen and hydrogen ... dry ... so you can't see it ... combining to form water on the edge of the glass". (F7)

View 4 "The water in the air sticks to the glass" (2xF4, F5, 4xF6, F7)

The older students who held this view normally supported their view with comments about molecules and particles.

"Air that has gone onto the side of the jar has turned into water. (Where does the water come from?) The moisture in the atmosphere ..." (F4)

From the teaching of science point of view it is of some interest to know the prevalence of these views, particularly the view that oxygen and hydrogen combine to form water on the glass. Responses to survey question No. 3 gave some indication of the prevalence of the various views.



3.5 Ice Melting

Those interviewed observed a block of ice melting on a teaspoon. When the pupils were asked "What is happening to the ice?", most of them had no difficulty in describing the event as melting and the interviewer investigated what the pupils considered were the essential differences between water and ice and what they perceived melting to be.

One S4 pupil showed a delightfully egocentric viewpoint.⁷

"It turns into water ... all it is ... it's just frozen water".
(What is the difference between frozen water and ordinary water?) "You can't drink it very good". (S4)

7. In addition to this child-centred view, one or two other students had the idea that frozen, or recently melted water was unpleasant to drink, and they seemed to indicate that they had first hand experience. As well, one sixth former had been informed that recently melted water was so oxygen-rich that skiers should not drink it.

Commonly held responses fall into three groups.

View 1 "It just melts and changes into water" (7xS4, F1, F2, F3, 2xF4, F5, F6, F7)

Many pupils could really add very little to the view that it just melts, or gets warmer and melts. This view covered a wide age range, for example here we have similar responses from a S4 pupil and a F7 pupil.

"The ice gets hot and it just melts". (S4)

("How does it melt?") "In the freezer it's sort of got a dull look about it. But out it's shiny. You can see it melting". ("I'd really like to know some more about this melting process".) "So would I!" (F7)

View 2 "It's above its melting temperature" (2xF2, 5xF3)

In this category we found responses which showed some appreciation of temperature dependence,

"The ice melted ... when water is put in a certain degree it freezes ... when it is warmed up again it melts back into water". (F3)

View 3 "The heat makes the particles move further apart" (F4, 3xF5, 3xF6, F7)

Some pupils used a general model which relates volume and temperature for many substances.

("What else happens when it melts?") "It's going to be more ... if you took the volume of that (the water) it is going to be more". ("Can you talk about what is happening in terms of molecules when it freezes?") "They go more compact". ("How do you see that?") "The colder the heat the less vibrations there are between them ... so that is why the ice doesn't take up as much room as when it is a liquid or gas ..." (15)

Unfortunately, this general model doesn't relate to what actually happens when water freezes. Moreover there are few familiar substances with melting points near room temperature for which the model does apply. If scientific knowledge is to be learnt as anything but isolated knowledge, it is so important that models can be tested by pupils, that they are tested against reality, and that they are related to real life experiences.

SUMMARY

One of the findings from this study was that the pupils interviewed could readily associate a technical term, often the appropriate technical term, with an event. The water "evaporates", "condenses" and "boils". On the other hand further questioning of pupils of all ages as to what they actually meant by these terms left us with a strong impression that even many older pupils had no sound scientific concepts underpinning these labels.

While some older pupils had obviously been exposed to a particle model, two aspects of their model need comment. First, the idea of change of state being critically temperature dependent (at a given pressure) was not evident in the interviews. Melting to many pupils is a gradual process almost unconnected with temperature. Secondly, the particle model appeared to be a rather abstract model, hardly, if at all, related to their everyday experiences. For example, the particle model for many pupils implied that liquids would be less dense than solids, yet the only example of a liquid/solid change with which they are familiar defies that rule.

This study confirms the work of our other studies. Children bring to science classes strongly held views about how and why everyday things behave as they do. In relation to their experiences these views appear, to them, to be logical and sensible. Unless teachers identify these views and design their teaching accordingly, some children's ideas will not change, or will change in unanticipated ways, as a result of formal science teaching.

PART 4 SUGGESTED TEACHING ACTIVITIES

The activities of this unit are planned to build on and reinforce children's views where these views are essentially similar to those of scientists, and to challenge and change children's views where these are found to be inconsistent or incompatible with those of scientists.

The TEACHER should USE the activities to:

- establish the children's views;
- challenge the children's view;
- if necessary, shift the children's view towards the consensus science view related to the activity

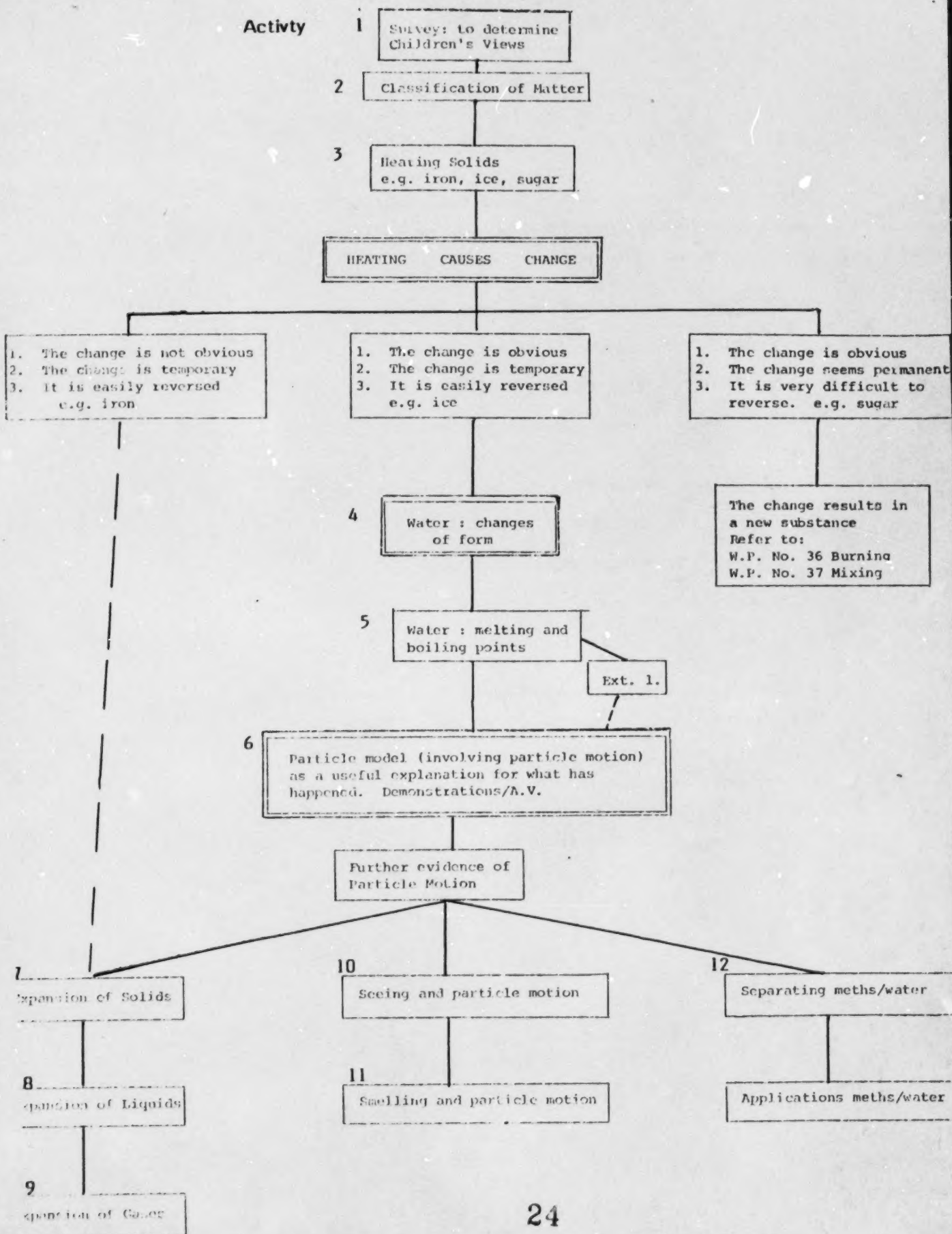
The CHILDREN should be INVOLVED in the activity to:

- clarify their own view;
- consider the usefulness of their view;
- consider other views;
- if necessary change their view ... about the central idea of the activity

On the following page you will see a framework showing the activities and the thinking behind the sequence of the activities.

NB Key ideas of the unit have double edging. Other than in one of the early critical activities (4) this unit does not include chemical changes resulting from heating and cooling various substances. The word particle(s) is used with purpose, for simplicity and unambiguity.

Activity



ACTIVITIES

4.1 The Survey (P 3-6)

Complete 2 copies; hand one in and keep a record of responses made in a science exercise book. By all means, do a hands count of responses to some questions to show the variation in thinking within the class.

4.2 Classifying Matter

With class draw up a list of 10-15 substances found in and around the home. Make sure some liquids and gases are included. List several ways of grouping these substances: eg. (a) eaten, not eaten

(b) poisonous, not poisonous

(c) solids, liquids, gases

Qstn What are the difficulties in grouping substances in these ways?

Ansr (a) Things such as cardboard, cloth can be eaten, but are not usually eaten

(b) A whiff of fly spray does not hurt you, but if you were to drink some, it could do real damage to you

(c) Even with solids/liquids/gases, where do you classify mud or toothpaste?

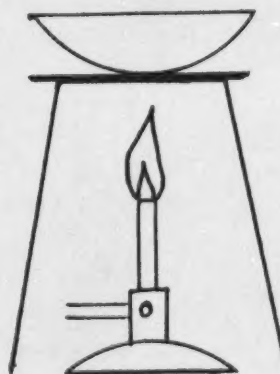
4.3 Heating Solids

Purpose: To find out what happens when solids are heated

What to do:

Pupils: Copy purpose (above)
Copy table (below)
Copy diagram

Teacher: Each group heats samples of the solids in an evaporating dish, one by one. Samples should include ones chosen by them and by you. The children should make predictions where possible, and be encouraged to work and observe very carefully before writing one or more sentences about what is seen. This activity could take 1-2 sessions.



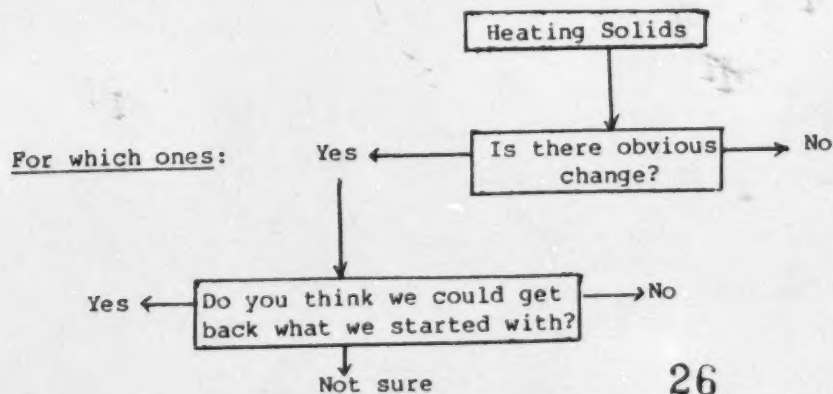
NB 'Keep a sample of each substance you heat so you can compare what you had with what you get!'

When iodine is heated, an inverted cool filter funnel held over the evaporating dish will ensure that some of the gaseous iodine recrystallises in a striking way. Or, you may like to leave iodine until activity 4.11.

Name	What we think we will see happen	What we did see happen	
		during heating	after heating
Ice			
Nail			
Camphor			
Copper Sulphate			
Salt			
Sugar			

Discussion

It is vital to gain as much from this activity as possible because it is the classification of observations made which provide the introduction and purpose for the following activities. In the discussion check for accuracy of observation. Then you may like to use this scheme for further classifying the observations.



For those where there is no obvious change, for example, heating a metal, mention that you are to return to these later on.

For those where there seems to be entirely new substances formed, (eg. the products from heating sugar, ammonium dichromate, copper sulphate crystals) mention that they involve what scientists call chemical changes. These changes are considered in other units (Refer to WP No 36, Burning, and WP No 37, Mixing). Some children will place camphor and iodine in this category - there seems to be new substances formed. You want to establish if this is indeed the case and are interested in changes which are easily reversed; that is, you can get back what you started with relatively easily. Such changes can be investigated in detail by considering firstly a very familiar substance, water.

By all means use part or all of the flow diagram on an OHP transparency to show children how the unit develops.

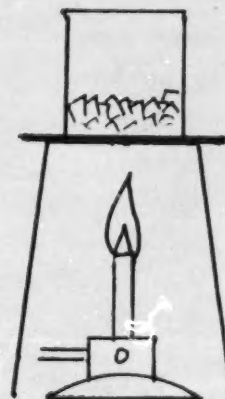
4.4 Changing Water

Purpose: To find out what actually happens when water melts/evaporates/condenses

What to do:

Pupils: Take beakers containing crushed ice; heat carefully
Complete: purpose
 diagram
 table below
Be very accurate in what you notice
Try not to use words such as "melt" or "evaporate" ,

Teachers: When water is boiling, have pupils place a dry cold saucer or beaker well above the boiling water. Put comments at *



Time	What we noticed	What we think happened

* when the saucer ...

Discussion

1. Check accuracy of observations made
2. Check for variety of comments made in column 3

What is this stuff that's given off when water boils? (air, steam, heat, hydrogen and oxygen). Refer to survey question 1; make a hands count of their responses; then does anyone want to change? How can you convince others that your response is the right one? Some students should suggest that as they know water is made up of hydrogen and oxygen, then it must be those two gases coming off. This would be a good time to look at their responses to the survey questions 2 and 3 as well. What evidence have we to show whose idea is right?

Many children are satisfied with an explanation of boiling/evaporating such as: millions of tiny bits of water, each so tiny that you can't see them, spread out and mix with the air (see pl6). However there are others who will take more convincing that their alternative view is not appropriate nor correct. For example, there is a significant number of children (see pl6) who hold the view that when water boils, or evaporates, hydrogen and oxygen are formed. You could use these two demonstrations for their benefit:

- A. You can show that hydrogen and oxygen is an explosive mixture. This can be done in a practical way by preparing and collecting hydrogen gas (add calcium to water and collect the gas by displacing water from a test tube). Test the combination (hydrogen and oxygen from the air) by bringing a lit taper near. It pops! Does the gas given off when water boils do the same? You may like to dramatise this by warnings etc. before lighting a match above boiling water in a beaker or kettle.
- B. 1. Put some dry ice (solid carbon dioxide) on a bench: watch
2. Crush some dry ice and spoon it into the neck of a large balloon; tie the neck of the balloon; watch - the balloon gets bigger.
- Qn. What is the gas that causes the balloon to get bigger
-air? Could be but we said we started with carbon dioxide
-heat? Heat is not a substance ...
-carbon dioxide gas? Bubble the gas in the balloon through limewater

-carbon and oxygen gas? If there is no black solid material left on the bench or in the balloon, and if the gas in the balloon does not rekindle a glowing splint, then carbon and oxygen have not been formed.

NB: It is presumed here that your students are aware of the common tests for carbon dioxide gas and oxygen gas. Also you may need to show them what carbon looks like.

4.5 Melting/Boiling Points

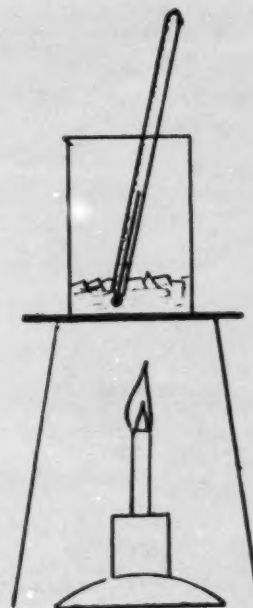
Purpose: To determine accurately melting and boiling temperatures

What to do:

Pupils: Again take beakers containing crushed ice; heat carefully.
Copy: purpose
diagram
chart below
Complete readings till the water has half boiled away

Teacher: Pupils may need to be shown how to use a thermometer. All pupils will be involved in taking the readings after activity is completed, pupils can be helped in plotting a heating curve as shown

Time/minutes	Temperature/°C



Questions:

1. At what temperature does most of the ice seem to melt?
2. What names are given for this temperature? Why?
3. At what temperature does water boil? (about 97 - 99°C often)

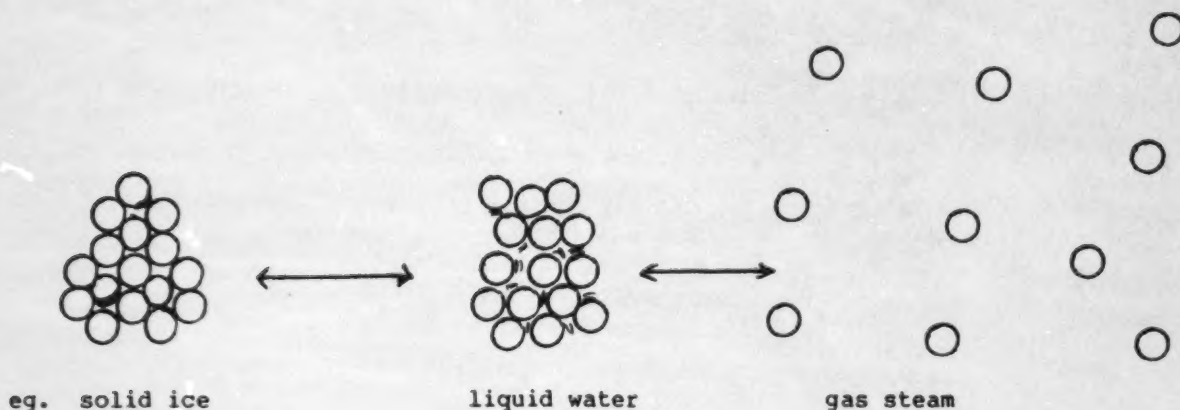
Teacher: Melting and Boiling points are temperature characteristic when a pure substance changes to another form (state). The activity gives the teacher the opportunity of dealing with the melting/dissolving conflict, and a further opportunity for further developing and refining the particle model. (See over, and also Extension 1, p. 34.)

4.6 A Particle Model

There are several methods of demonstrating particles of solids, liquids and gases; their order and motion.

- Clear blackboard diagrams
- Using a magnetic board, with small magnetised discs representing the particles of a substance
- Using small coins or discs on an overhead projector

This type of diagram needs explanation and discussion:



NB: Try to gain these ideas from the students:

There is increasing particle movement $S \rightarrow L \rightarrow G$

There are increasing gaps (containing nothing) as you change $S \rightarrow L \rightarrow G$

There are not new particles created

The individual particles of any substance are very, very small but do not change in size when heated.

Films

Evidence for Atoms and Molecules

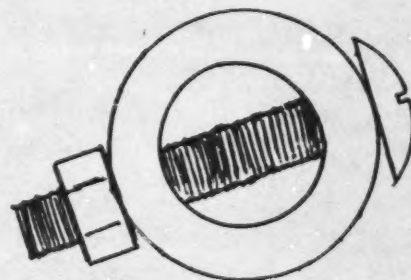
A Model for Matter

4.7 Expansion of Solids

Purpose: To find out what happens when solids expand?

What to do: WASHER AND BOLT

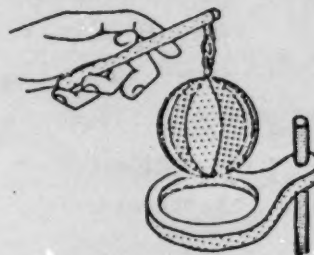
Pupils: Screw the nut onto the bolt until it just fits across the washer.
 Remove the washer, hold in tongs and heat strongly.
 Will it now fit across the bolt?



Quickly unscrew the nut until the bolt fits across the washer. Allow the washer to cool. Measure the gap between the bolt and washer. Record your findings.

BALL AND RING

Study the apparatus
Decide what you are going to do
Record your findings under:
What I did
What I saw
What I think happened



Teacher: You should refer to the variety of responses given in survey question 11. Do the pupils still hold the views given. Discuss the usefulness of views held.
Do the two activities.

Questions:

1. Which view fits the evidence from the preceding activities?
2. What view do you hold now regarding the expansion of solids. Why?

4.8 Expansion of Liquids

Purpose: To find out what happens when liquids are heated (but not to boiling)

What to do:

Pupils: In this activity, a full flask of cold coloured water is heated. The water is coloured so it can be seen more easily. These points should be made while demonstrating what to do.

- (a) Fill the flask right to the top with cold coloured water.
- (b) When the bung is pushed in, don't worry if a little water is spilt. Wipe the water away.

- (c) The initial water level in the tube should be seen above the bung. Mark the spot.
- (d) Those observing carefully should notice that initially the water level drops slightly because of the (greater) expansion of the glass container. Then the level rises.
- (e) After 5 (?) minutes mark the tube where the water level is, and again after 10 minutes. Do not allow the water to boil.



Record: What we did
What we saw
Why we think it happened (Refer to responses to survey question 6)
The diagram

Relate to what happens in thermometers.

4.9 Expansion of Gases

Purpose To find out what happens when gases are heated and cooled

What to do:

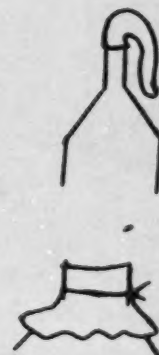
- Pupils: a. Place a balloon over a flask (or bottle) and heat the flask by pouring hot water over it. Observe carefully.

Answer these questions:

Is there any more air in the bottle and balloon now?
How do you explain what has happened?

- b. Heat an empty flask, then stretch and tie a piece of balloon rubber over the opening. Allow the flask to cool.

What do you see happening?
Why does this happen?



What do you see happening?
Why does this happen?

Teacher:

- a) Refer to survey question 10 to gain the pupil's views
If children think that most (or all) the air goes into the balloon because hot air rises, ask: what will happen if I turn the flask upside down? (Get a hands count) Turn the flask upside down.

If the pupils views about air pressure are not clear you should provide suitable activities at a later date. You can refer to the Resource Unit Air Pressure 4/21 (Department of Education 1980).

4.10 Evidence for Particle Movement and our Senses (1)

Purpose: What happens when iodine is heated and cooled?

Iodine is worth using because some pupils think that all gases are colourless.

What to do:

Pupils: Collect a few crystals only
Heat these few crystals very gently in a corked flask⁸
Try not to get the neck of the flask warm
Watch what happens very carefully
Copy purpose
Copy and fill in this chart

	What I think	What our group thinks	My view (if it changes) after class discussion
What is the purple stuff?			
Where does it come from?			
How much space does it take up? (compared with what you started with)			
What happened when you stopped heating the flask?			
What is the stuff that has formed?			
How could you tell?			

8. Instead of a corked flask you can put iodine in an evaporating dish. Place a piece of filter paper with holes cut in it over the dish (this cuts down the heat transfer). Place an inverted glass filter funnel above the dish and paper. Long needle like crystals of iodine should form at the neck of the filter funnel.

Teacher: Check on individual/group responses to the above questions

Allow pupils to heat iodine crystals that have condensed on neck of flask

Introduce these three views regarding why iodine gas takes up more space than iodine solid

1. The particles of iodine get much bigger
2. Tiny particles of iodine move round more and spread out
3. The colour comes out of iodine and spreads out.

Which view is preferred (do a hand count). Ask for reasons. Relate to the particle model discussed earlier.

For further work on coloured substances refer to Mixing (Working Paper No 37).

4.11 Evidence for Particle Movement and our Senses (2)

Purpose: What happens when we smell things

What to do:

Pupils: Collect a small piece of camphor
Heat it carefully in a beaker
Observe what happens
Copy purpose
Copy and fill in this table

	What I think	What our group thinks	My view (if it changes) after class discussion
What did you see?			
What do you think happens to the camphor?			
How can we smell the scent of flowers?			
How can we smell a perfume?			

Teacher: You should refer to the responses given to survey question 5. You can place a dish of ammonium hydroxide or carbon disulphide on a side bench. Ask what is noticed?

Develop the view that a sensible way of explaining why we smell anything is that very tiny particles of the substance (camphor, perfume etc) spread out and come into contact with delicate sense organs in the nose.

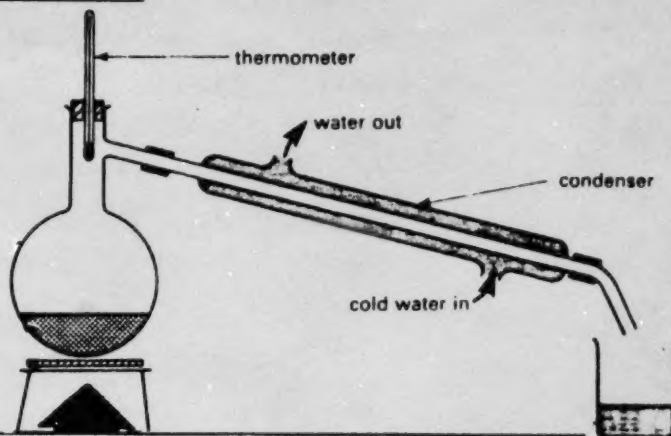
4.12 Different changes with different substances

Purpose: To separate meths and water

Best done as a teacher demonstration.

Pupils can copy purpose, diagram, and table below.

Once the meths has all evaporated, and condensed, replace the beaker. Do not boil to dryness!



Time/Mins	Temperature/°C	What we noticed
0	21	
6	81	
Etc		

Questions:

1. What do you think is in this first beaker? How could you tell?
2. How can we explain what we have seen in this activities?
3. How does this fit in with your views of water as a typical liquid?
4. Where in NZ is a big industry based on this process? (Marsden Point Oil Refinery - find out some details)

N.B. A mixture of glycerine and water in equal parts can be used also.
Glycerine boils at 290°C.

Extension 1

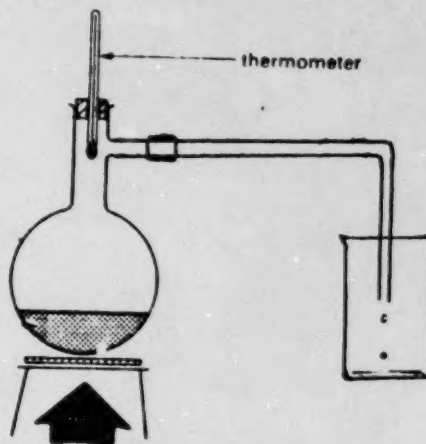
Purpose: To find out how Purr'n Puss died?

Information

For Pupils: You discover your lovable pet cat Purr'n Puss dead on the garage floor. A soft drink bottle has been knocked over and lies beside dear Purr'n. Some colourless liquid is still in the bottle. Could it be the liquid that caused Purr'n's death? Your mother suggests you bring the bottle to school, and you ask your science teacher how you could find out what the liquid is. Your teacher suggests finding out what the precise boiling point of the liquid is. This would tell you if the liquid is water, or some other liquid (eg. some poisonous substance mixed with water). You would not taste the liquid, nor should you smell it.

For Teachers: These two colourless liquids would be suitable for pupils to use using the boiling/condensing apparatus as shown.

- (a) A concentrated salt solution (either sodium chloride or potassium chloride solution) The BP should be about 101-104°C depending on the amount of the salt used.
- (b) Iso propan 2-ol BP 82°C



NB: Relate this exercise to what forensic scientists do at DSIR.

What other tests could be used in such cases

Who did kill Purr'n? You supply the conclusion to this tragic tale!